SPECIFICATION

Production Method of Curved-Surface Metal Mold Having Fine Uneven Structure and Production Method of Optical Element using this Metal Mold

Field of the Invention

[0001] This invention relates to a method for manufacturing curved-surface metal molds having a fine uneven structure serving as an antireflection structure or the like, a method for manufacturing the curved-surface metal molds having the fine uneven structure by using easily workable materials to form a curved surface, and a method for manufacturing optical elements with the metal mold.

Background Art

[0002] Conventionally, optical elements such as optical pickups and aspherical lenses made of glass, plastic or other light-transmitting materials are subjected to a surface treatment to prevent light reflection on the light incident surface of a substrate. This surface treatment includes a method in which a multilayer film composed of laminated thin dielectric films is formed on a surface of a light-transmitting substrate by vacuum deposition or the like and a method in which fine, dense unevenness are provided on a surface of an optical element.

[0003] An antireflection structure of fine, dense uneven shape formed on the surface of the optical element is known to be formed by molding plastic with a metal mold (e.g. Japanese unexamined patent publication No. 62-96902).

[0004] The metal mold for forming the optical element having the antireflection

structure of fine, dense uneven shape is formed with a substrate made from quartz or silicon. The substrate is subjected to an etching process to form a specified antireflection structure thereon and plated to form the metal mold.

[0005] By the way, in order to provide the above-mentioned antireflection structure on a lens, such as a lens for optical pickups, having a specified curvature, a predetermined treatment is required to form a curved surface on the quartz or silicon which will be a substrate.

Brief Summary of the Invention

Problems to be Solved

[0006] In the case of a lens having a complex surface shape like an aspherical lens, it is difficult to work on the substrate to form the metal mold. In other words, the quartz or silicon used as a substrate is unworkable and often subjected to fractures and chips in the course of manufacture of the substrate. Therefore, the manufacture of the metal mold is time consuming and expensive.

[0007] This invention is made to solve the above-discussed conventional problems and has an object to provide a method for readily manufacturing metal molds to add the fine, dense uneven shape to a lens having complex surface shapes such as an aspherical lens.

[0008] In addition, this invention has an object to provide a method for readily manufacturing optical elements, including the lens having complex surface shapes such as an aspherical lens, with the fine, dense uneven shape provided on the

surface of the optical elements.

Means to Solve the Problem

[0009] A production method of the metal mold having the fine uneven structure according to the invention is characterized by: forming a silicon-base film on a curved-surface base substrate formed in a specified shape; etching the silicon-base film with a mask to form a specified shape of a fine uneven pattern; bonding metal used for the metal mold on the silicon-base film with the pattern of the fine uneven structure formed thereon; and removing the silicon-base film after the pattern of the fine uneven structure is transferred to the metal used for the metal mold to form the metal mold with the fine uneven structure on a surface thereof.

[0010] The pattern of the fine uneven structure is characterized by being an antireflection pattern.

[0011] The mask is made of a photoresist and an antireflective film may be formed between the curved-surface base substrate and silicon-base film.

[0012] A mold release material film may be formed between the curved-surface base substrate and silicon-base film.

[0013] In addition, the silicon-base film can be a silicon dioxide film formed by a sputtering method.

[0014] In addition, a production method of the metal mold having the fine uneven

structure according to this invention is characterized by: forming a silicon-base film on a curved-surface base substrate formed in a specified shape; providing a mask on this silicon-base film, the mask having a specified shaped fine uneven pattern on an effective area part of the mask and the uneven pattern changing its volume percent toward the outside; etching the silicon-base film using this mask to form a fine pattern composed of fine unevenness gradually becoming deeper from the outer region to the inner region and having a predetermined depth and shape on the effective area; bonding metal used for the metal mold to the substrate with the uneven pattern formed thereon; and releasing the metal used for the metal mold from the substrate to form a metal mold after the uneven pattern is transferred to the metal used for the metal mold.

[0015] In addition, a production method of an optical element, according to this invention, is characterized by: forming a silicon-base film on a curved-surface base substrate formed in a specified shape; etching the silicon-base film using a mask to form a pattern of a specified shaped fine uneven structure; bonding metal used for the metal mold to the silicon-base film with the pattern of fine uneven structure formed thereon; removing the silicon-base film after the pattern of the fine uneven structure is transferred to the metal used for the metal mold to form a metal mold having the fine uneven structure on the curved surface; attaching the metal mold to at least either of a stationary mold or moving mold; and performing an injection molding with the stationary mold and moving mold to manufacture the optical element having the fine uneven structure on at least one of surfaces thereof.

Effects of the Invention

[0016] As discussed above, according to this invention, a curved-surface base substrate having a specified curved surface shape can be readily formed even if it has a complex shape such as a spherical surface and axisymmetric aspherical surface. Based on the curved surface of this curved-surface base substrate, a metal mold having a specified curved-surface with a fine, dense uneven structure can be formed even if it has a complex shape such as a spherical surface and axisymmetric aspherical surface.

[0017] In addition, the provision of the antireflective film allows the resist to be pattered more densely, thereby being able to form the curved-surface metal mold having the antireflection structure of further fine, dense uneven shape.

[0018] The use of the mold release material film facilitates the separation between the metal mold side and substrate side.

[0019] In addition, the use of the curved-surface metal mold having the antireflection function gradually becoming deeper from the outer region to the inner region and the antireflection structure with the unevenness of conical shape formed at a predetermined pitch on the effective area allows the filled resin to be readily peeled off from the outer region, thereby eliminating the possible breakage of the metal mold (stamper) and molded articles.

Brief Description of the Drawings

[0020] FIGS.1A-1H are cross-sectional views illustrating a step-by-step manufacturing process of a curved-surface metal mold having an antireflection

structure according to the first embodiment of this invention.

FIGS. 2A-2I are cross-sectional views illustrating a step-by-step manufacturing process of a curved-surface metal mold having an antireflection structure according to the second embodiment of this invention.

FIGS. 3A-3J are cross-sectional views illustrating a step-by-step manufacturing process of a curved-surface metal mold having an antireflection structure according to the third embodiment of this invention.

FIGS. 4A-4H are cross-sectional views illustrating a step-by-step manufacturing process of a curved-surface metal mold having an antireflection structure according to the fourth embodiment of this invention.

FIG. 5 is a plan view illustrating an exposure process to gradually deepen the antireflection function of the optical element from the outer region toward inner region.

FIG. 6 illustrates the relation of adherability between the metal mold and molded article in each area of the optical elements manufactured according to this invention.

FIG. 7 is a cross-sectional side view illustrating configuration and structure of a molding tool used for the manufacturing method of the optical element according to this invention.

Explanation of reference number

[0021]1 curved-surface base substrate

2 a silicon dioxide film (SiO_2) film

3 resist film

4 metal layer

4a,4b metal mold (stamper)

Detailed Description of the Preferred Embodiments

[0022] The following is a description of embodiments of this invention with reference to drawings. FIGS. 1A-1H are cross-sectional views illustrating a step-by-step manufacturing process of a curved-surface metal mold having an antireflection structure composed of dense, fine unevenness according to the first embodiment of this invention.

[0023] As shown in FIG. 1A, a curved-surface base substrate 1 with a specified curved surface, such as a spherical surface and axisymmetric aspherical surface used in an objective lens for optical pickups, collimating lens and other lenses, is prepared. This curved-surface base substrate 1 is made of a metal substrate which can be easily curved, a resin substrate formed by the metal mold or a glass substrate. In this embodiment, good cuttable aluminum alloy or carbon free copper are polished with a rotating diamond tool of an ultra precision microfabrication equipment to have a mirror-finished specified curved-surface like a spherical surface or axisymmetric aspherical surface.

[0024] Subsequently, as shown in FIG. 1B, a silicon dioxide film (SiO_2) film 2 with a thickness of approximately 500 nm to 1 μm is formed as a silicon-base film on the specified curved surface of the curved-surface base substrate 1 by a sputtering method. In this embodiment, a silicon dioxide film (SiO_2) film 2 with a thickness of 900 nm is formed by an RF magnetron sputter using a SiO_2 target. The film is formed under the conditions: with the SiO_2 target; a substrate temperature of 200 degrees C; an argon (Ar) gas flow rate of 20 sccm; and a pressure of 1.36 Pa.

[0025] As shown in FIG. 1C, a resist is then applied on the silicon dioxide film (SiO_2) film 2. This resist application is performed by spin-coating a resist, for example, the trade name "TDUR-P009" manufactured by TOKYO OHKA KOGYO CO., LTD., at 4000 rpm to consequently form a resist film 3 having a thickness of 600 nm.

[0026] Subsequently, as shown in FIG. 1D, the applied resist film 3 is exposed to light and developed to form a resist pattern 30. In this embodiment, a two-beam interference exposure system (wavelength λ = 266 nm) is used as an exposure system. The first exposure is made with an exposure power of 750 mJ, and then a multi-exposure is made with an exposure power of 750 mJ after the substrate is turned at 90 degrees. Then, development is made with the trade name "NMD-W" manufactured by TOKYO OHKA KOGYO CO., LTD. to form a resist pattern 30 with a multitude of conical projections at a pitch of 250 nm.

[0027] Next, as shown in FIG. 1E, the silicon dioxide film (SiO_2) film 2 is patterned using the above-discussed resist pattern 30 as a mask by reactive ion etching (RIE). In this embodiment, the trade name "NLD-800" manufactured by ULVAC, Inc. is

used as an RIE etching system. Conical grooves 21 with a processed depth of 500 nm are formed using a mixed gas of C_4F_8 and CH_2F_2 as an etching gas, an antenna power source of 1500 W and a bias power source of 400 W, at an etching rate of the silicon dioxide film (SiO_2) of 12 nm/sec.

[0028] After that, as shown in FIG. 1F, removal of the resist film making up the resist pattern 30 by oxygen plasma ashing brings a specified curved-surface antireflection structure 2a made of silicon dioxide film (SiO_2) and provided with fine, dense conical unevenness thereon.

[0029] Then, as shown in FIG. 1G, a metal layer 4 to be a metal mold (stamper) is formed on the antireflection structure 2a made of the silicon dioxide film (SiO_2). The metal layer 4 is formed as follows: a nickel (Ni) seed layer is formed by sputtering; a nickel layer is formed on the nickel seed layer by electrolytic plating; and the rear surface is polished. The metal layer 4 having a predetermined thickness is thus formed to be a mold (stamper).

[0030] At last, as shown in FIG. 1H, by mechanically releasing the mold (stamper) 4a from the boundary of the silicon dioxide film (SiO_2) and metal layer 4, the curved-surface metal mold 4a according to the embodiment is obtained having the antireflection structure with the fine, dense conical unevenness formed at a pitch of 250 nm.

[0031] According to the above-described embodiment, the curved-surface base substrate 1 having a specified curved surface, even if the specified curved surface is

complicated in shape like a spherical surface and axisymmetric aspherical surface, can be readily formed by the ultra precision microfabrication equipment. By undergoing the above steps B-H along the curved surface of the curved-surface base substrate 1, the curved-surface metal mold 4a having a specified curved surface and an antireflection structure of fine, dense uneven shape can be formed even if the curved surface is complicated in shape like a spherical surface and axisymmetric aspherical surface.

[0032] Next description will be made on the second embodiment of this invention with reference to FIGS. 2A-2I. FIGS. 2A-2I are cross-sectional views illustrating a step-by-step manufacturing process of a curved-surface metal mold having an antireflection structure according to the second embodiment of this invention. The same components as those in the first embodiment are denoted with the same reference numbers and their detailed descriptions are omitted to avoid repetition.

[0033] Just as with the first embodiment, as shown in FIG. 2A, a curved-surface base substrate 1, having a specified curved surface shape such as a spherical surface and axisymmetric aspherical surface used in an objective lens for optical pickups, collimating lens and other lenses, is prepared.

[0034] Subsequently, as shown in FIG. 2B, an antireflective material 11 is provided on the specified curved surface of the curved-surface base substrate 1. In the second embodiment, a chromium (Cr) film with a thickness of 100 nm is formed first, and a chrome-oxide (CrO) film with a thickness of 100 nm is formed on the chromium film as the antireflective material 11 by a sputtering method. In

addition to the above materials, the antireflective material 11 can be Al_2O_3, CeO_2, LaF_3, MgF_3, TiO_2, TiN, ZnS, ZrO_2 or the like.

[0035] After that, as shown in FIG. 2C, a silicon dioxide film (SiO_2) film 2 having a thickness from approximately 500 nm to 1 μm is formed on the antireflective material 11 formed on the curved-surface base substrate 1 by the sputtering method. The silicon dioxide film (SiO_2) film 2 formed in this embodiment has a thickness of 900 nm. This silicon dioxide film (SiO_2) film 2 is formed under the same conditions as the first embodiment.

[0036] Then, as shown in FIG. 2D, a resist film 3 with a thickness of 600 nm is formed on the silicon dioxide film (SiO_2) film 2. This resist film 3 is also the same resist film used in the first embodiment.

[0037] Subsequently, as shown in FIG. 2E, the applied resist film 3 is exposed to light and developed, in the same manner as the first embodiment, to form a resist pattern 30 with a multitude of conical projections formed at a pitch of 250 nm.

[0038] Next, as shown in FIG. 2F, the silicon dioxide film (SiO_2) film 2 is patterned, in the same manner as the first embodiment, using the above resist pattern 30 as a mask by reactive ion etching (RIE). This patterning forms conical grooves 21 each having a processed depth of 500 nm. This patterning is also performed under the same conditions as the first embodiment.

[0039] After that, as shown in FIG. 2G, removal of the resist 30 by oxygen plasma

ashing brings a specified curved-surface antireflection structure 2a made of silicon dioxide film (SiO_2) and provided with fine, dense conical unevenness on the surface.

[0040] Then, as shown in FIG. 2H, a metal layer 4 to be a mold (stamper) is formed on the antireflection structure 2a made of the silicon dioxide film (SiO_2).

[0041] At last, as shown in FIG. 2I, by mechanically releasing a mold (stamper) 4a from a boundary of the silicon dioxide film (SiO_2) and metal layer 4, the curved-surface metal mold 4a according to the embodiment is obtained having an antireflection structure with conical unevenness formed at a pitch of 250 nm.

[0042] In the above-described second embodiment, in addition to the effect of the first embodiment, the antireflective material 11 allows the resist to be patterned more densely, thereby being able to form the curved-surface metal mold 4a having the antireflection structure of finer, denser uneven shape.

[0043] Next description will be made on the third embodiment of this invention with reference to FIGS. 3A-3J. FIGS. 3A-3J are cross-sectional views illustrating a step-by-step manufacturing process of a curved-surface metal mold having an antireflection structure according to the third embodiment of this invention. The same components as those in the first and second embodiments are denoted with the same reference numbers and their detailed descriptions are omitted to avoid repetition.

[0044] As shown in FIG. 3A, a curved-surface base substrate 1, having a specified

curved surface shape such as a spherical surface and axisymmetric aspherical surface used in an objective lens for optical pickups, collimating lens and other lenses, is prepared just as with the first embodiment.

[0045] Subsequently, as shown in FIG. 3B, a mold release material 12 having an antireflection function is provided on the specified curved surface of the curved-surface base substrate 1. In the third embodiment, a resist having an antireflection function against ultraviolet rays is applied and hard-baked to be used as the mold release material 12. In this embodiment, the trade name "SWK-248DTr" manufactured by TOKYO OHKA KOGYO CO., LTD. is used as the resist and hard-baked at 180 degrees C.

[0046] After that, as shown in FIG. 3C, a silicon dioxide film (SiO_2) film 2 having a thickness of approximately from 500 nm to 1 μm is formed on the mold release material 12 formed on the curved-surface base substrate 1 by the sputtering method. The silicon dioxide film (SiO_2) film 2 formed in this embodiment has a thickness of 900 nm. This silicon dioxide film (SiO_2) film 2 is formed under the same conditions as the first embodiment.

[0047] Then, as shown in FIG. 3D, a resist film 3 with a thickness of 600 nm is formed on the silicon dioxide film (SiO_2) film 2. This resist film 3 is the same used in the first embodiment.

[0048] Subsequently, as shown in FIG. 3E, the applied resist film 3 is exposed to light and developed in the same manner as the first embodiment, to form a resist

pattern 30 with a multitude of conical projections formed at a pitch of 250 nm.

[0049] Next, as shown in FIG. 3F, the silicon dioxide film (SiO_2) film 2 is patterned, in the same manner as the first embodiment, using the above-described resist pattern 30 as a mask by reactive ion etching (RIE). This patterning forms conical grooves 21 each having a processed depth of 500 nm. This patterning is performed under the same conditions as the first embodiment.

[0050] After that, as shown in FIG. 3G, removal of the resist 30 by oxygen plasma ashing brings a specified curved-surface antireflection structure 2a made of silicon dioxide film (SiO_2) and provided with fine, dense conical unevenness on the surface.

[0051] Then, as shown in FIG. 3H, a metal layer 4 to be a mold (stamper) is formed on the antireflection structure 2a of the silicon dioxide film (SiO_2).

[0052] After that, as shown in FIG. 3I, the mold (stamper) 4a is mechanically released together with the silicon dioxide film (SiO_2) from the boundary of the mold release material 12 and silicon dioxide film (SiO_2).

[0053] Subsequently, as shown in FIG. 3J, the resist for releasing the mold, which adheres to the mold (stamper) side is removed by oxygen plasma, and only the silicon dioxide film (SiO_2) 2a is then removed by reactive ion etching (RIE). Etching gas used is CHF_3. Thus, a curved-surface metal mold 4a having the antireflection structure with conical unevenness formed at a pitch of 250 nm according to this embodiment is obtained.

[0054] In the above-described third embodiment, the separation between the mold (stamper) side and base substrate 1 side can be readily achieved.

[0055] By the way, when optical elements are formed by filling resin into the above-described metal mold with the antireflection structure of the fine unevenness formed, the resin is filled into the fine pattern having a high aspect. This increases a load upon release of the metal mold from the resin. Especially, adherability significantly increases at the boundary between the non-patterned area and patterned area, and therefore causes breakage of the stamper and molded article. Hence, this fourth embodiment is made for decreasing the load upon the release. For this purpose, the unevenness of the antireflection function are gradually deepened from the outer region of the optical element toward the inner region to gradually increase the load upon the release, thereby readily releasing the filled resin from the outer region. The following description is on the fourth embodiment with reference to FIGS. 4A-4H and 5.

[0056] FIG. 4A-4H are cross-sectional views illustrating a step-by-step manufacturing process of a curved-surface metal mold having an antireflection structure according to the fourth embodiment of this invention, while FIG. 5 is a plan view illustrating an exposing process for gradually deepening the unevenness of the antireflection function of the optical element from the outer region of the optical element toward the inner region. The same components as those in the first, second and third embodiments are denoted with the same reference numbers and their detailed descriptions are omitted to avoid repetition.

[0057] As shown in FIG. 4A, a curved-surface base substrate 1, having a specified curved surface shape such as a spherical surface, axisymmetric aspherical surface used in an objective lens for optical pickups, collimating lens or other lenses, is prepared.

[0058] Subsequently, as shown in FIG. 4B, a silicon dioxide film (SiO_2) film 2 with a thickness of 900 nm is formed on the specified curved surface formed on the curved-surface base substrate 1 by an RF magnetron sputter. This silicon dioxide film (SiO_2) film 2 is formed under the same conditions as the first embodiment.

[0059] Then, as shown in FIG. 4C, a resist is applied on the silicon dioxide film (SiO_2) film 2. This resist application is performed by spin-coating a negative resist used with electron beams at 3000 rpm. The negative resist is, for example, the trade name "NEB22" manufactured by Sumitomo Chemical Co., Ltd. Thus a resist film 3a with a thickness of 600 nm is formed.

[0060] Subsequently, as shown in FIG. 4D and FIG. 5, an electron beam is irradiated to the applied resist film 3a using an electron beam (EB) lithography system. The irradiation energy is increased toward the outer region. For example, as shown in FIG. 5, the electron beam is irradiated by one-hundred micro meter square for printing. An effective area 30a is irradiated with the electron beam at energy of 10 $\mu C/cm^2$; an area 30b1 outside the effective area 30a is irradiated with the electron beam at energy of 12 $\mu C/cm^2$; an area 30b2 outside the area 30b1 is irradiated with the electron beam at energy of 14 $\mu C/cm^2$; and the

outermost area 30b3 is irradiated with the electron beam at energy of 16 $\mu C/cm^2$. After being printed by the EB, the resist film 3a is post-exposure baked (PEB) at 110 degrees C by a hot plate for two minutes, and then developed for two minutes with developer No. "MF CD-26" manufactured by Shipley Far East, Ltd. As a result, a resist pattern 31 is formed having a multitude of conical projections formed at a pitch of 250 nm on the effective area 30a and formed on the areas 30b so as to be wider toward the outside. This resist pattern 31 is a mask with a volume ratio of the uneven pattern changing from the effective area toward the outside.

[0061] Next, as shown in FIG. 4E, the silicon dioxide film (SiO_2) film 2 is patterned using the above-described resist pattern 31 as a mask by reactive ion etching (RIE). In this embodiment, the trade name "NLD-800" manufactured by ULVAC, Inc. is used for the RIE etcher; a mixed gas of C_4F_8 and CH_2F_2 is used as etching gas; the antenna power source is 1500 W; the bias power source is 400 W; and the etching rate of the silicon dioxide film (SiO_2) is 12 nm/sec to form grooves 21 with a processed depth of 500 nm on the effective area. As a result, a pattern is formed so that the antireflection-functional grooves are gradually deepened from the outer region toward the inner region in the areas outside the effective area 30a.

[0062] After that, as shown in FIG. 4F, removal of the resist 30 by oxygen plasma ashing brings a specified curved-surface antireflection structure 2b of the silicon dioxide film (SiO_2) having the antireflective function gradually deepening from the outer region toward the inner region in the areas outside the effective area 30a and the specified fine, dense unevenness in the effective area 30a.

[0063] Then, as shown in FIG. 4G, a metal layer 4 to be a mold (stamper) is formed on the antireflection structure 2b made of the silicon dioxide film (SiO_2). The metal layer 4 is formed as follows: a nickel (Ni) seed layer is formed by sputtering; a nickel layer is formed on the seed layer by electrolytic plating; and the rear surface is polished. The metal layer 4 having a predetermined thickness is thus formed to be a mold (stamper).

[0064] At last, as shown in FIG. 4F, by mechanically releasing a mold (stamper) 4a from the boundary of the silicon dioxide film (SiO_2) and metal layer 4, the curved-surface metal mold 4b according to this embodiment is obtained having the antireflection structure with the conical unevenness formed at a pitch of 250 nm on the effective area 30a and the antireflective grooves gradually deepening from the outer region toward the inner region in the areas outside the effective area 30a.

[0065] As discussed above, the curved-surface metal mold 4b, having the antireflection structure with the antireflective function gradually deepening from the outer region toward the inner region in the areas outside the effective area 30a and the conical unevenness formed at a predetermined pitch in the effective area 30a, allows the filled resin to be easily peeled off from the outer region, thereby eliminating the possible breakage of the stamper and molded articles.

[0066] A molded article is formed using the metal mold with the antireflection structure formed at a uniform depth as shown in FIG. 1. In addition, a molded article is formed using the metal mold as shown in FIG. 4. Comparison was made in respect to adherability of the molded articles to the metal mold shown in FIG. 1

and the metal mold shown in FIG. 4. As a result, as shown in FIG. 6, according to this invention, the adherability diminishes in an area 11b positioned from the outer region to the outer edge. Consequently, according to the fourth embodiment of this invention, when the resin is filled in the mold, the resin can be readily peeled off from the outer region of the mold, thereby eliminating the possible breakage of the stamper and molded articles.

[0067] The structure of this fourth embodiment can provide the same effect even if the structure is applied to the above-discussed second and third embodiments.

[0068] Although the silicon dioxide film (SiO_2) film is used as a silicon-base film in the above embodiments, a silicon (Si) film, silicon nitride (SiN) film and other films are also available. Further, an SOG film formed by spin-coating organic silane or the like is also available as the silicon-base film.

[0069] Next, the manufacture of optical elements using the metal mold according to this invention will be described with reference to FIG. 7. FIG. 7 is a cross-sectional side view illustrating configuration and structure of a molding tool used for manufacturing the optical elements according to this invention. This molding tool comprises a stationary mold 60 and a moving mold 70. When the moving mold 70 is pushed against the stationary mold 60, a cavity 80 is created between the molds 60 and 70. At a part of the periphery of the cavity 80, a gate 81 linking to the cavity 80 is formed. Molten plastic resin is supplied to this cavity 80 through the gate 81 to fill up the inside of the cavity 80.

[0070] The stationary mold 60 includes a first member 61 in the middle and a second member 62 on the periphery side, and both are made from steel and fixed in a mutually integrated manner. The first member 61 includes a smooth concave molding surface 61a facing the moving mold 70, while the second member 61 includes a molding surface 61b, which is a ring-shaped groove, arranged on the periphery of the molding surface 61a. The molding surface 61a of the first member 61 corresponds to one surface of a lens (not shown) which is a molded article, while the molding surface 62a of the second member 62 corresponds to a flange provided on the periphery of the lens.

[0071] The moving mold 70 includes a pushing part 71 which is a molding member in the middle and a main body 72 supporting the pushing part 71 at its periphery. On the end of the pushing part 71, the mold (stamper) 4a manufactured by any one of the above-discussed methods according to the first to fourth embodiments of this invention is attached. The metal mold 4a is formed to have a concave surface corresponding to the other surface of the lens and includes the antireflection structure 40a made of the fine, dense uneven surface on the concave surface. The peripheral molding surface 72a defined by the main body 72 corresponds to the flange on the periphery.

[0072] The pushing part 71 is fitted in a hole 72b provided in the main body 72 so as to slide in the axial (X) direction. After mold opening, which means both molds 60 and 70 are disengaged from each other, this pushing part 71 is moved toward the stationary mold 60 with respect to the main body 72, thereby releasing the lens laid on the moving mold 70 side.

[0073] Next, lens molding using the molding tool shown in FIG. 7 will be described in brief. First, the moving mold 70 is engaged with the stationary mold 60 to close the molding tool. At this time, the stationary mold 60 and moving mold 70 are aligned using an alignment mechanism such as a fitting pin (not shown) and then secured. Such mold closing creates the cavity 80, in the shape made by closing and joining the molding surfaces 61a, 61b of the stationary mold 60 and the molding surface 40a, 72a of the moving mold 70, between the molds 60 and 70.

[0074] Next, molten plastic resin is injected into the cavity 80 created between the molds 60 and 70. The molten plastic resin is introduced through the gate 81 to the cavity 80 between molds 60 and 70 to fill up the cavity 80.

[0075] Subsequently, the molten plastic resin filled in the cavity 80 dissipates heat and is cooled down. The molten plastic resin injected into the cavity 80 usually has a temperature of 200 to 300 degrees C and therefore is cooled and cured upon contact with the molding surfaces 40a, 72a, 61a, 61b of the molds 60, 70 which are maintained at generally 100 to 180 degrees C. At this time, the molten plastic resin almost completely penetrates into the fine uneven pattern formed on the molding surface 40a of the pushing part 71.

[0076] Next, the molten plastic resin filled in the cavity 80 waits to be completely cured. After all, a lens corresponding to the shape of the cavity 80 is obtained. One surface of the lens is a smooth convex surface corresponding to the molding surface 61a, while the other surface of the lens is a convex surface having the

antireflection structure corresponding to the molding surface 40a. In addition, a flange is formed on the periphery of the lens, corresponding to the molding surfaces 61b and 72a.

[0077] After that, the mold opening is performed to disengage the moving mold 70 from the stationary mold 60. As a result, the molded article stays on the side of the moving mold 70, but is separated from the stationary mold 60.

[0078] Then, the pushing part 71 accommodated in the main body 72 is driven toward the stationary mold 60 by a driving device (not shown). This driving process completely demolds, in other words, separates the lens from the moving mold 71.

[0079] Thus obtained lens is applicable to an optical pickup device and so forth. Although the metal mold with the fine uneven pattern is attached to the moving mold 70 in the above embodiment, the metal mold can be attached to the stationary mold 60 and moving mold 70 as appropriate based on the design of the optical element to be manufactured, for example, either of the stationary mold 60 or moving mold 70, or both.

[0080] Although the antireflection structure is cited as an example use of the fine, dense uneven shape in the above embodiment, the present invention can be applied to any cases to manufacture the optical-element pattern structure having the other functions as long as the optical elements require the fine, dense uneven shape. For example, the present invention is applicable to manufacture fine patterns included

in wave plates and diffraction gratings.

[0081] It should be understood that the embodiments disclosed herein are to be taken as examples and are not limited. The scope of the present invention is defined not by the above described embodiments but by the following claims. All changes that fall within meets and bounds of the claims, or equivalence of such meets and bounds are intended to be embraced by the claims.

Industrial Applicability

[0082] This invention is applicable to the method for manufacturing diffraction gratings for optical pickup, wave plates for optical pickups, lenses for optical pickups, display covers for cellular phones and other optical elements to provide the antireflection structure on surfaces of these elements.